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ENVIRONMENT

STRATEGIES THAT REDUCE PARTICULATE PESTICIDE HAZARDS TO WILDLIFE

J R Mason

US Department of Agriculture, Animal and Plant Health Inspection Services, Denver Wildlife Research Center, c/o Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104, USA.

Introduction

The popularity of no-till conservation farming is increasing in the US. These practices generally benefit wildlife because they do not involve the broadcast application of pesticides and because they provide food and cover. However, such conservation farming does involve the use of pesticides applied as particulate formulations; these include granular pesticides, pelleted baits, and chemically-treated seeds. Some of these products are toxic when ingested by wildlife (Hill and Camardese, 1984; Greig-Smith, 1988) and predators and scavengers that consume poisoned animals are also at risk.

Federal agencies in the US have begun to restrict the use of some particulate formulations because of the dangers they present to birds and mammals. There is ample statutory justification for these restrictions (eg., Migratory Bird Treaty Act, 16 USC 703-711; Bald Eagle Protection Act 16 USC 668-668d). This restriction has led to studies in which particulate formulations have been modified, the aim of these investigations being to develop products with significantly reduced risks. A variety of modifications have been considered, including: manipulation of particle size and shape; manipulation of particle hardness; use of colours either as repellents or as camouflage; and incorporation of chemical repellents.

Particle Size or Shape

The sizes and shapes of particulate formulations frequently overlap the size and shape of natural grit (Best, 1992). Such overlap probably contributes to the ingestion of particulate formulations by birds, since many species show clear grit size and shape preferences (Best and Gionfriddo, 1991). This fact notwithstanding, there is little practical likelihood that the manipulation of these features will significantly reduce the hazard of particulate formulations to birds. This is because species differ greatly in the size and shape of grit particles that they prefer (Best and Gionfriddo, 1991) and also the range of particle sizes and shapes that can be economically produced and effectively used is limited.

Particle hardness

Whether or not manipulation of particle hardness would affect the probability of ingestion is unclear. Few, if any, data bear on this issue. However, since particulate formulations are apparently consumed as grit, the likelihood of ingesting soft particles is probably less than that of ingesting hard particles. Indeed, soft particles may be actively avoided, particularly if they become tacky when wet (Avery *et al*, 1989). Systematic investigation of whether hardness affects the likelihood of ingestion of particulate formulations is warranted.

Colour

Changing the colour of particulate formulations could influence detection, and subsequently, ingestion by wildlife. Colour is clearly an important determinant of avian foraging but its importance is context-dependent (Greig-Smith and Rowney, 1987). Red or orange insects, for example, are avoided by birds because they are typically unpalatable or toxic, but red or orange fruits are typically safe and preferred. Aversiveness largely depends upon association of the colour cue with post-ingestional sickness (Mason and Reidinger, 1983) and so use of aposematic (warning) colours may not deter ingestion of bait by birds which encounter it for the first time. Accordingly, the use of cryptic colours (*i.e.* camouflage) might represent a more effective means of deterring ingestion. *A priori*, it seems likely that giving particulate formulations colours that resemble the coloration of the substrate would minimize opportunities for detection and accidental ingestion. This hypothesis does not appear to have been explicitly tested, although there is anecdotal evidence that cryptic colours reduce (albeit not eliminate) ingestion (W. Smith, FMC Corporation, *pers. comm.*).

Chemical Repellents

The use of repellent tastes (non-volatile substances) and odours (volatile substances) in particulate formulations is receiving increasing attention. The utility of repellent tastes is limited for several reasons. First, the effectiveness of taste repellents depends on the substance being taken into the mouth but the ingestion of only a few particles of some particulate formulations is lethal (Balcomb *et al*, 1984). Second, taste repellents are frequently selected because they are noxious to humans, and not because they repel wildlife. Abundant research has demonstrated that there is broad interspecific variation in taste sensitivity and many birds and some mammals are insensitive to tastes that humans commonly reject. An example of this is denatonium benzoate which is sold as a wildlife repellent but the available evidence suggests that it is only offensive to humans (Nolte *et al*, 1993). Finally, there are ontogenetic differences in taste sensitivity and substances that repel young animals may not repel older animals and vice versa (*e.g.* Beauchamp and Mason, 1991).

One exception to the premise that taste repellents have little utility may be the development of particulate formulations that are inherently aversive but relatively non-toxic. For example, cucurbitacins are triterpenoid glycosides that occur chiefly in plants belonging to the Cucurbitaceae and Cruciferae families. These substances protect against insect herbivory and have been considered for use in commercial insecticide formulations. In laboratory tests, cucurbitacins are significantly repellent to birds at concentrations well below those that might produce toxicosis (Figure 1). These substances appear to be aversive to mammals as well (*pers. obs.*).

Unlike taste repellents, there are volatile, odorous substances that might effectively reduce the hazards of particulate formulations. These are aversive at a distance and sufficient data exist to guide the selection of materials that repel wildlife. Examples of such substances include cinnamyl alcohol derivatives, cinnamic acid esters, d-pulegone and various anthranilate and acetophenone compounds (*e.g.* Crocker and Perry, 1990). For example, in a recent outdoor aviary test, methyl anthranilate was incorporated into a particulate formulation and presented to cowbirds (*Molothrus ater*) for 15 days on tilled earth in large outdoor enclosures. Although untreated bait disappeared from the substrate in significant quantities, the disappearance of treated baits was statistically indistinguishable from zero (Mason *et al*, 1993).

The available evidence suggests that these volatile, odorous substances are aversive because they are chemical irritants. They are effective because they stimulate trigeminal free nerve endings (*i.e.* pain receptors) in the eyes, nasal capsule and mouth. At least some of these substances are relatively non-toxic. For example, the available toxicity values for oral administration of methyl anthranilate by gavage (LD_{50} data) or in feed (LC_{50} data; five day exposure period plus three day post-exposure observation) are: rat LD_{50} = 3288 mg kg^{-1} BW, quail LD_{50} >290 mg kg^{-1} BW, mouse LC_{50} = 3900 mg kg^{-1} diet, quail LC_{50} >5600 mg kg^{-1} diet. One important caution, however, is that while avian trigeminal stimulants are sometimes effective against mammals (for example, methyl anthranilate), mammalian trigeminal stimulants, such as capsaicin, piperine, zingerone, allyl isothiocyanate) are rarely effective against birds (Mason and Otis, 1990).

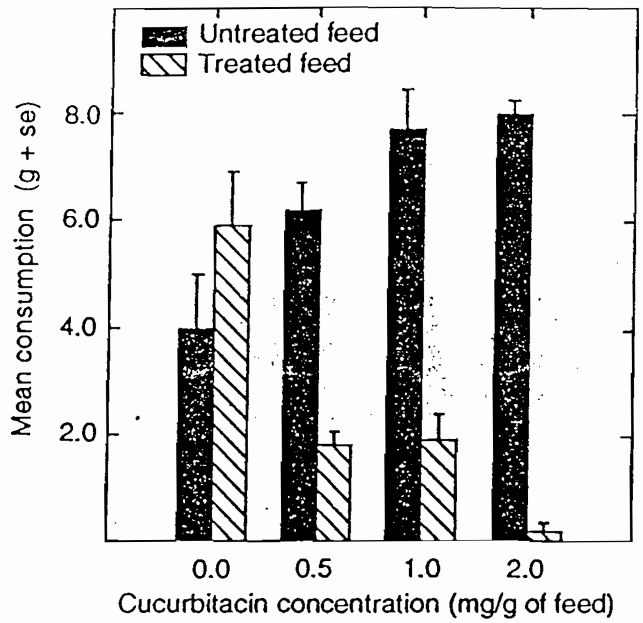
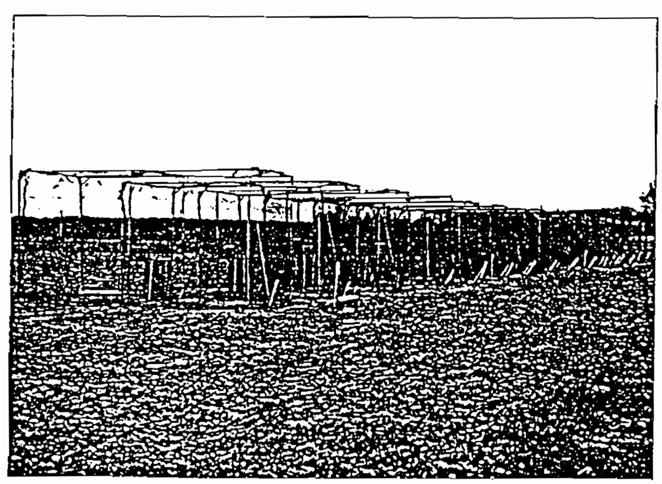


Figure 1. Mean consumption by 40 starlings (*Sturnus vulgaris*) of feed containing cucurbitacin and untreated feed in two-cup tests (Mason and Turpin, 1990). Vertical bars represent standard errors.



Outdoor enclosures used to test the effectiveness of methyl anthranilate as a bird repellent additive to formulated pesticide baits (Mason et al, 1993). Rutgers Agricultural Experiment Station, Centerton, NJ, March and April 1992.

Conclusions

There are encouraging data which suggest that odour repellents (cinnamic acid, methyl anthranilate, ortho-aminoacetophenone, d-pulegone) can be used to reduce substantially or eliminate the hazards of particulate formulations to wildlife. Nevertheless, to ensure significant reductions in the danger that these substances present, other features should be considered in product formulation. These include the use of colours that make formulations indistinct from the substrate (brown, grey, black), and a soft texture that diminishes the likelihood that particles will be ingested as grit. Parametric studies that evaluate these possibilities should be strongly encouraged in order to assure the availability of granular and pelleted pesticides.

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Dr J Russell Mason received his MA and PhD in psychology from Clark University in Worcester, Massachusetts. Subsequently, he received post-doctoral training as a research associate in the chemistry department at Brown University and as a staff scientist in chemical ecology at the Monell Chemical Senses Center. At present, Dr Mason is a Project Leader for the Denver Wildlife Research Center of the US Department of Agriculture, a Full Member of the Monell Chemical Senses Center of Philadelphia, and an Adjunct Full Professor at the University of Pennsylvania. He is the author of over 100 refereed publications, book chapters, and technical reports, most dealing with wildlife repellents and attractants.